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Development of an Inquiry-Based + AI Learning Activity in Teaching Rate of Chemical Reaction at Ethno chemistry Context

Mohaisah P. Boloto[1] , & Edna B. Nabua[2]

[1,2] Mindanao State University

Iligan Institute of Technology

Philippines

ABSTRACT

This study aimed to develop an inquiry-based learning activity enhanced with artificial intelligence (AI) for teaching the rate of chemical reaction within an ethnochemistry context and to evaluate its effects on learners' conceptual understanding. Additionally, the study explored learners' perceptions of using an inquiry-based AI-supported activity for this chemistry topic. The learning activity was designed following inquiry-based principles and integrated AI support via ChatGPT to facilitate questioning, clarification, and exploration. Readability analyses using the Flesch-Kincaid and SMOG indices indicated that the material was suitable for Grade 9 learners. Expert validation further confirmed the activity's acceptability in terms of content accuracy, clarity, organization, and appropriateness for the target audience. A one-group pretest–posttest design was employed with 18 learners, using a 15-item multiple-choice test. Results indicated a statistically significant improvement in posttest scores compared to pretest scores ($t(17) = 7.59$, $p < 0.0001$), demonstrating enhanced conceptual understanding following exposure to the activity. Qualitative interview data revealed that learners initially expressed hesitation regarding AI use due to policy uncertainties but gradually engaged in collaborative inquiry, exhibited increased learner agency, and sustained motivation. Integration of culturally familiar contexts further heightened interest, even when complete conceptual mastery was not immediately achieved. Overall, the findings suggest that inquiry-based learning supported by AI and grounded in ethnochemistry can effectively promote conceptual understanding, engagement, and collaborative learning in chemistry, particularly when AI functions as a scaffold for inquiry.

Keywords: AI, Ethno chemistry, Inquiry-based learning.

1. INTRODUCTION

The learning of chemistry requires the integration of the three levels of chemical representation: macroscopic, submicroscopic, and symbolic. Connecting these levels is essential for meaningful conceptual understanding, as emphasized by Schwedler and Kaldewey (2019) and as originally proposed by Johnstone (1991) and further discussed by Renvall and Kurtén (2024). Despite this, students often struggle to transition between these representations, particularly because the submicroscopic level cannot be directly observed (Salame & Makki, 2021; Visser et al., 2023). Research further indicates that topics such as the rate of chemical reaction pose additional challenges, as they require learners to relate observable phenomena to underlying molecular processes (Rahmawati et al., 2022; Rahayu et al., 2024; Sidauruk & Anggraeni, 2024). Traditional instructional approaches, which frequently emphasize rote memorization, exacerbate these difficulties by undermining conceptual understanding and reducing student motivation (Prunici, 2023).

Inquiry-based learning (IBL) has been widely recognized as an effective pedagogical approach for enhancing conceptual understanding in chemistry. IBL encourages active student participation, enabling learners to construct knowledge through exploration and guided inquiry (Aidoo et al., 2022; Gomez, 2025). Moreover, IBL can be aligned with culturally responsive teaching practices, which leverage learners' cultural knowledge to make learning more meaningful and effective (Gay, 2010; Halim et al., 2022). Ethnochemistry, which integrates chemical concepts with cultural knowledge, provides an ideal context for applying culturally responsive IBL by allowing learners to interpret abstract chemical ideas through familiar, culturally relevant experiences (Singh & Chibuye, 2016; Sutrisno et al., 2020; Oladejo et al., 2022; Wahyudiati, 2022).

In parallel, artificial intelligence (AI) is increasingly being explored in chemistry education for its potential to support personalized learning, provide feedback, identify learning gaps, and foster deeper conceptual understanding (Iyamuremye et al., 2024; Selvam, 2024). However, few studies have examined the integration of AI with inquiry-based approaches, particularly in the context of ethnochemistry. Addressing this gap, the present study seeks to develop an inquiry-based learning activity enhanced with AI for teaching the rate of chemical reaction within an ethnochemistry framework. Specifically, the study aims to assess learners' conceptual understanding following engagement with the activity and to explore their perceptions of using an inquiry-based, AI-supported approach in this culturally contextualized chemistry topic.

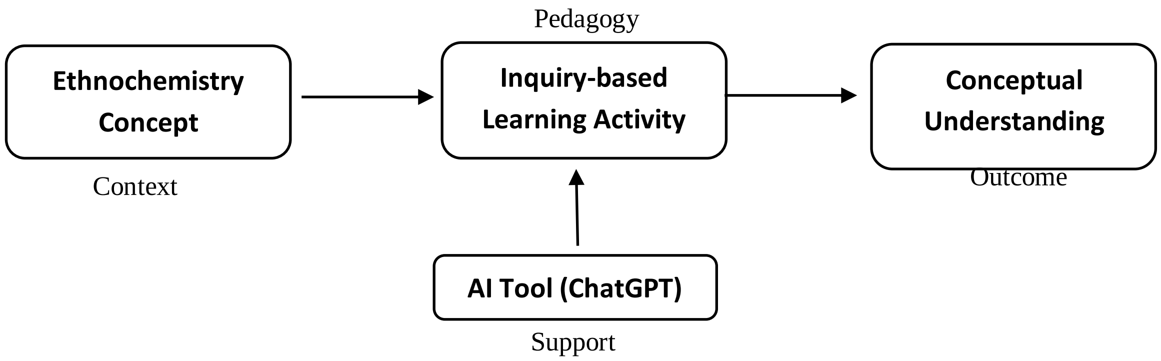

Figure 1. Conceptual Framework of the Study

Figure 1 presents the conceptual framework of the study, which can be interpreted through the Context–Input–Process–Output (CIPO) model. In this framework, ethnochemistry provides the contextual foundation by situating learning within learners' cultural perspectives. The learning activity, supported by ChatGPT, constitutes the primary input designed to scaffold learners' inquiry. The process component involves students actively engaging in the inquiry-based activity, promoting exploration, questioning, and conceptual reasoning. Finally, the output of the framework is the learners' conceptual understanding of the rate of chemical reaction, reflecting the effectiveness of the AI-supported, culturally contextualized inquiry-based approach.

2. METHODOLOGY

This study employed a mixed-methods research design. The quantitative component aimed to assess the conceptual understanding of 18 Grade 10 learners following exposure to an inquiry-based learning activity enhanced with artificial intelligence (AI) for teaching the rate of chemical reaction within an ethnochemistry context. A one-group pretest–posttest design was implemented, using a 15-item multiple-choice test administered before and after the intervention to measure changes in conceptual understanding. The qualitative component involved semi-structured interviews with one representative from each of four learner groups, with the objective of exploring learners' perceptions regarding the use of an inquiry-based, AI-supported activity in teaching the rate of reaction in the ethnochemistry context.

The intervention consisted of a researcher-designed inquiry-based learning activity that incorporated ChatGPT as a scaffolding tool to support learners' questioning, exploration, and conceptual reasoning. The activity was contextualized using Sakurab (Allium chinense G. Don) to integrate culturally relevant examples and was structured according to the 5E instructional model to promote engagement, exploration, explanation, elaboration, and evaluation. Prior to implementation, two science teachers validated the learning activity to ensure the accuracy of content, clarity of organization, appropriateness of presentation, and suitability of language for the target learners.

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3. RESULT AND DISCUSSION

A readability analysis was conducted on the learning activity using the Flesch–Kincaid and SMOG indices, yielding scores of 8.59 and 8.91, respectively, indicating that the material is appropriate for Grade 9 learners. In addition, the learning activity underwent expert validation by two science teachers prior to implementation. Using a structured rating sheet, the evaluators assessed the alignment of the activity with the DepEd Most Essential Learning Competencies (MELCs) for the topic. They also noted that the length of the activity could potentially reduce learners' motivation to complete it. This observation aligns with Biggs' (2014) assertion that instructional activities and assessments must be deliberately designed to support student learning, with clearly defined objectives established prior to instruction. Research further emphasizes that overly demanding or lengthy learning tasks can negatively affect learner motivation and engagement (Evans et al., 2024), underscoring the importance of aligning learning objectives with appropriately designed activities to optimize both comprehension and engagement.

Table 1. Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	.162	18	.200*	.949	18	.409
Posttest	.232	18	.011	.905	18	.069

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table 1 presents the assessment of normality for the pretest and posttest scores using the Shapiro–Wilk test. The results indicated that both the pretest ($p = 0.409$) and posttest ($p = 0.069$) scores met the assumption of normality. Consequently, a paired-samples t-test was conducted to examine the difference between the pretest and posttest scores, allowing for the evaluation of changes in learners' conceptual understanding following the intervention.

Comparison of Pretest and Posttest Scores

A 15-item multiple-choice test was administered as both a pretest and posttest to evaluate learners' conceptual understanding of the rate of chemical reaction. The test was validated for readability using the SMOG index and for content accuracy prior to implementation. The pretest was first conducted to assess learners' prior knowledge, followed by administration of the same test as a posttest after the intervention. Scores from both assessments were analyzed to determine whether exposure to the inquiry-based, AI-supported learning activity produced a statistically significant improvement in conceptual understanding. A paired-samples t-test was employed to examine these differences, addressing the second objective of the study.

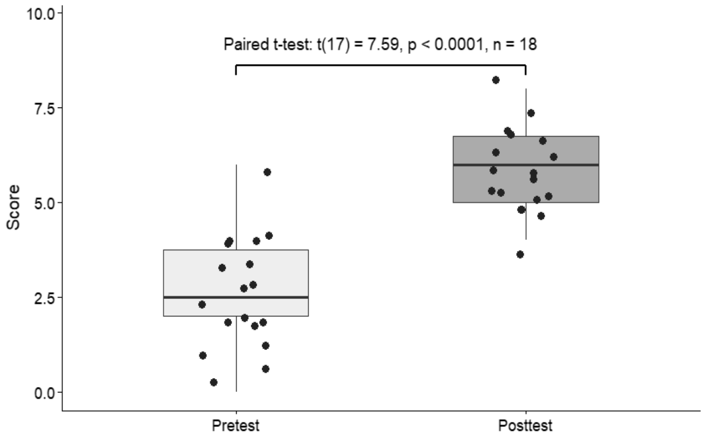

Figure 2. Distribution of Students' Pretest and Posttest Scores

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The results indicate a statistically significant difference between learners' pretest and posttest scores following participation in the inquiry-based, AI-supported learning activity. The paired-samples t-test revealed a substantial increase in scores, $t(17) = 7.59$, $p < 0.0001$ ($n = 18$), suggesting that the observed improvement is unlikely to be attributable to chance. These findings demonstrate that the intervention effectively enhanced learners' conceptual understanding. The pretest scores reflected learners' initial difficulties with the topic, consistent with prior research indicating that students struggle to grasp the rate of chemical reaction (Sidauruk & Anggraeni, 2024). In contrast, the higher and more clustered posttest scores suggest both improved performance and greater consistency in conceptual understanding following the intervention.

These findings also underscore the efficacy of inquiry-based learning (IBL) in promoting conceptual understanding. Meta-analytic evidence indicates that IBL engages learners actively, which enhances comprehension more effectively than pedagogical approaches that rely primarily on passive learning (Minner, Levy, & Century, 2010). Furthermore, integrating AI tools such as ChatGPT can enrich the inquiry process by supporting personalized learning, facilitating data analysis, and fostering critical thinking, thereby amplifying conceptual gains (Kunnath & Botes, 2025).

Finally, situating the inquiry activity within an ethnochemistry context likely contributed to learners' engagement and understanding. Prior studies suggest that culturally contextualized chemistry instruction, which connects abstract chemical concepts to learners' indigenous knowledge and local practices, can enhance motivation and facilitate meaningful learning (Oyeyemi et al., 2024; Junaidi et al., 2025). Collectively, the integration of inquiry-based pedagogy, AI support, and cultural relevance appears to have produced significant improvements in learners' conceptual understanding, as evidenced by the posttest results.

Learners' Perceptions of the use Learning Activity

Table 2. Learners' Perceptions of the Learning Activity

Student Code	Response Meranaw/Filipino	Theme	Description
G101	"Nagulat po kami nong nalaman namin na gagamit kami ng ChatGPT kasi na naba kami gina allow a musar ron………" -We were shocked at first when we learned that we would be using ChatGPT because we are not usually allowed to use it. "Isa minitabang iyan rkami a group na mas malbod a kyasaboti ame ko mga questions. Pero mahirap a sabotn so pd ron, kailangan talaga mag ask ta ko mga pd ta" - It helped us understand the questions more easily, but some of its responses were harder to understand, so we had to discuss them with our groupmates.	From initial hesitation to collaboration	The learner initially experienced uncertainty toward AI use but reported that ChatGPT supported understanding of the task while encouraging group discussion to clarify complex explanations.
G106	"First na di akn katawan so topic ago mya amaze ako about ko sakurab. Nagulat ako kay ChatGPT na alam niya yung Sakurab." - At first, I did not know much about the topic, and I was amazed that ChatGPT had information about Sakurab.	Cultural engagement with partial understanding	The learner reported limited prior knowledge and expressed surprise at AI's access to information but indicated that some explanations remained difficult to fully understand.

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	"medyo ame syabot so explanation ron i ChatGPT" - we only slightly understood some of ChatGPT's explanations.		
G113	"Mas pakahelp skaniyan rkami kasi po nahihirapan kami minsan intindihin yung mga questions." -ChatGPT provided more help to us because some of the questions were hard to understand. "Isa a minitabang iyan ko activity ame na mas kyalbudan kami ron ago adn a mga concept a myalearn ame" "Pwede bs ta ron misa about ko mga pagusarn tano lagid o Sakurab asar a iexplain karon" -It was also possible to ask about the materials we used, such as Sakurab, as long as we described them clearly.	AI-supported clarification and contextual inquiry	Students found ChatGPT helpful in clarifying difficult questions, supporting their understanding of the activity, and enabling them to inquire about culturally familiar materials such as Sakurab, which contributed to learning new concepts.
G116	"Honestly, mas madali siyang maintindihan po kasi kapakay ta a mag ask always about sa gyuto a topic ago kapakay bs a pikiconfirm tawn lagid o siwa ame a pyakabgay ame sa research as evidence po." -Honestly, it was easier to understand because we were allowed to ask ChatGPT many times about the topic. We were also able to ask it to confirm information by requesting evidence. Pero na problema na minsan na paulit-ulit so question ron kasi na lagid a nahihirapan siyang intindihin minsan yung question naming" -Sometimes our questions had to be repeated because it seemed difficult for ChatGPT to understand what we were asking.	Repeated inquiry	Students found ChatGPT helpful in clarifying difficult questions, supporting their understanding of the activity, and enabling them to inquire about culturally familiar materials such as Sakurab, which contributed to learning new concepts.

The interviews revealed a clear progression in learners' experiences as they engaged with the inquiry-based, AI-supported learning activity. Initially, learners exhibited hesitation, largely attributable to uncertainty regarding the policies governing the use of ChatGPT. This aligns with findings by Chan and Hu (2023), who reported that students often express concern about ambiguous regulations surrounding generative AI tools. Muñoz et al. (2023) emphasized that educators should facilitate learners' responsible use of ChatGPT rather than instill apprehension, noting that government support for generative AI can enhance engagement and learning outcomes. Preparing learners to interact effectively with AI is increasingly important, as these technologies are expected to play an integral role in their future professional and academic lives (Halaweh, 2023).

Over time, learners' initial hesitation transitioned into collaborative inquiry and greater learner agency. They did not rely exclusively on ChatGPT; instead, they engaged in peer discussions when AI-generated explanations were

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challenging to comprehend. This underscores the social dimension of inquiry-based learning, wherein understanding is constructed through dialogue and collaborative reasoning. Empirical evidence indicates that inquiry-based learning integrated with AI can foster collaborative engagement and enhance conceptual learning (Kotsis, 2024; Penn & Ramnarain, 2024).

Furthermore, learners reported heightened interest when the AI-mediated activity incorporated culturally familiar content, even when full comprehension of the material was not immediately achieved. Research in culturally responsive chemistry instruction supports the integration of learners' indigenous knowledge as a means of enhancing motivation and facilitating deeper conceptual understanding (Oyeyemi et al., 2024; Junaidi et al., 2025). Collectively, these findings suggest that an inquiry-based learning approach augmented with AI, when situated within a culturally relevant context, can promote sustained engagement, collaborative learning, and active inquiry, even in the presence of initial hesitation or partial understanding.

4. CONCLUSION

In conclusion, the developed and refined inquiry-based learning activity, augmented with AI support, for teaching the rate of chemical reaction within an ethnochemistry context demonstrated both readability and alignment with the prescribed learning competencies. Quantitative analysis revealed a statistically significant improvement in learners' posttest scores, indicating enhanced conceptual understanding following the intervention. These findings corroborate prior research suggesting that inquiry-based learning, when integrated with AI support, can foster active learning, critical thinking, and meaningful conceptual comprehension. Qualitative evidence from learner interviews indicated an initial hesitation toward using ChatGPT, primarily due to policy uncertainty. However, learners gradually transitioned to collaborative inquiry, exhibited increased agency, and sustained engagement throughout the activity. Additionally, the incorporation of culturally familiar contexts contributed to heightened interest and motivation, even when full conceptual understanding was not immediately attained. Collectively, these results underscore the potential of combining inquiry-based pedagogy, AI scaffolding, and culturally responsive contexts to enhance chemistry learning outcomes.

5. RECOMMENDATION

Based on the findings of this study, the following recommendations are proposed for future research:

1. Learning activities that integrate inquiry-based approaches with AI support may be carefully aligned with the learning competencies prescribed by the Department of Education to ensure curriculum relevance and instructional effectiveness.

2. Future studies may consider extending the implementation period, incorporating multiple inquiry-based learning activities and iterative inquiry cycles, and employing larger and more diverse learner samples to enhance generalizability and the robustness of findings.

3. Researchers may investigate structured prompting strategies and scaffolding techniques that can guide learners in interpreting, evaluating, and effectively utilizing AI-generated explanations within science learning contexts, thereby maximizing the pedagogical potential of AI tools.

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